Chapter 2
DESCRIPTION OF THE WATER BODY

INTRODUCTION

The St. Lucie River and Estuary and its watershed are located on the southeastern coast of Florida in Martin and St. Lucie counties. The St. Lucie River and Estuary watershed encompasses about 781 square miles and is divided into five major basins and several small basins (**Figure 2**). The western basins are predominantly agricultural with about 70 percent of land in citrus and improved pasture. The two eastern basins (North St. Lucie and Tidal) are more urban with about 45 percent of the land devoted to agricultural activities. The St. Lucie Canal (C-44) is an important component of the Central and Southern Florida (C&SF) Project and is used, along with the Caloosahatchee River (C-43), primarily for water releases from Lake Okeechobee when lake levels exceed United States Army Corps of Engineers (USACE) regulation schedules (USACE, 2000). In addition to regulatory discharges for flood protection, the river and estuary also receive water deliveries from the lake to maintain water levels for navigation and water supply. The C-44 basin is particularly dependent on the lake for supplemental water supply and aquifer recharge (SFWMD, 1998a).

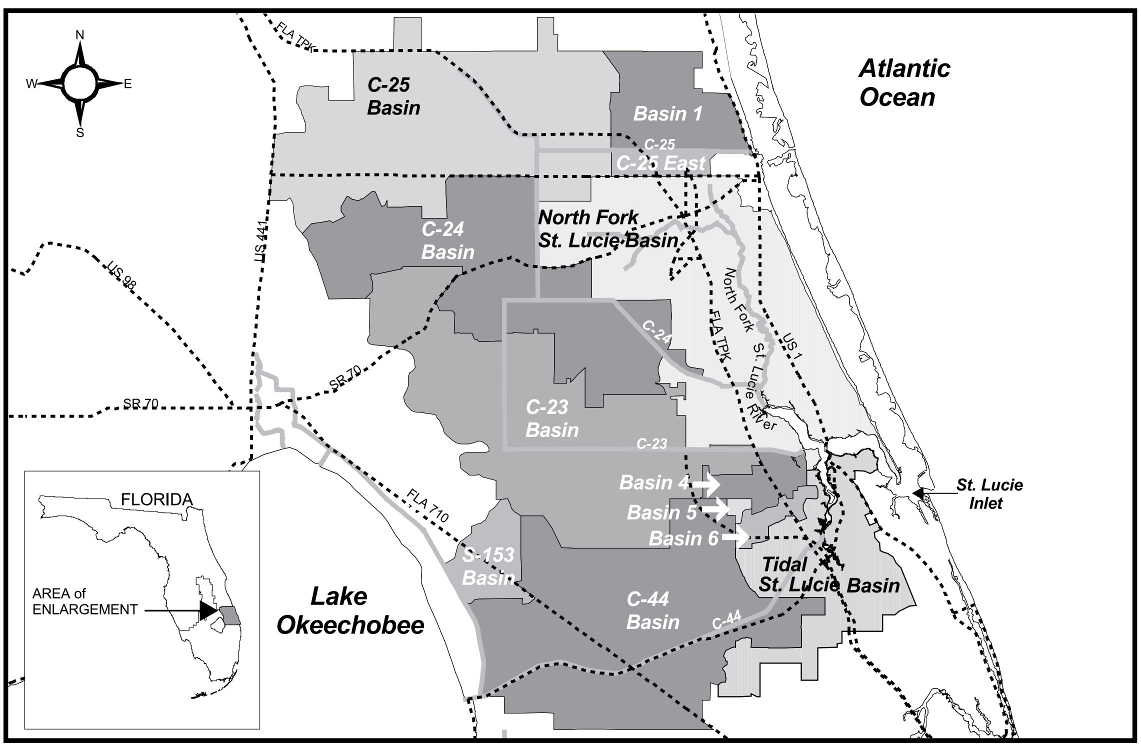


Figure 2. Major Drainage Basins, Rivers, and Canals in the St. Lucie Watershed

CLIMATE, RAINFALL, AND SEASONAL WEATHER PATTERNS

The main components of the hydrologic cycle in the St. Lucie watershed are precipitation, evapotranspiration, surface water flow, and ground water flow. The climate is classified as subtropical. The average seasonal temperatures range from 64 degrees Fahrenheit (^{O}F) during the winter to about 81 ^{O}F during the summer (University of Florida, 1993).

The 52-year average annual rainfall in the region is approximately 51 inches (Ali and Abtew, 1999), but varies considerably from year to year (**Figure 3**). Florida has a distinct wet season from May through October, and a dry season from November through April. About 72 percent of the annual rainfall occurs during the May through October wet season. The maximum monthly average rainfall is 7.52 inches in September (St. Lucie County) and the minimum monthly average rainfall is 1.93 inches in December (Martin County). Monthly rainfall displays a higher measure of relative variability during the dry period. Rainfall also varies spatially, with rainfall amounts generally decreasing from east to west.

Evapotranspiration is the sum of evaporation and transpiration, and is generally expressed in inches per year. In South Florida, approximately 45 inches of water per year is returned to the atmosphere through evapotranspiration. The excess of average precipitation over average evapotranspiration is equal to the combined amounts of average surface water runoff and average ground water recharge.

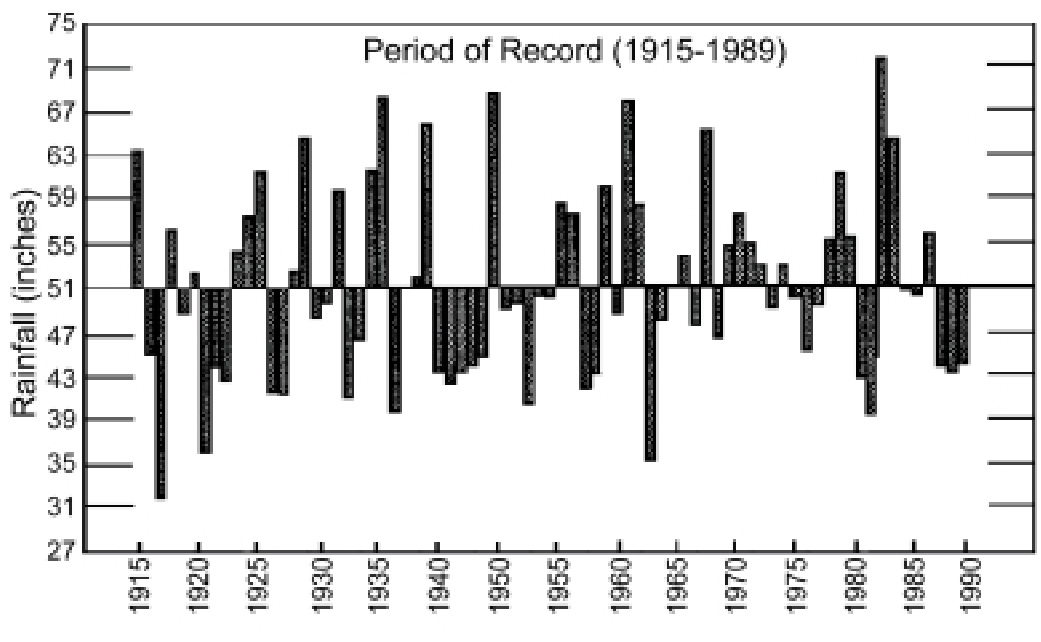


Figure 3. Variation from Annual Average Rainfall (Ali and Abtew, 1999)

PREDEVELOPMENT HYDROLOGY

Prior to development, most of the region was characterized by nearly level, poorly drained lands subject to frequent flooding. The natural surface drainage systems included large expanses of sloughs and marshes such as St. Johns Marsh, Allapattah Slough (also referred to as Allapattah Flats), Cane Slough, and the Savannas (**Figure 4**). Drainage systems with higher conveyance included the North and South Forks of the St. Lucie River, Ten Mile Creek, Five Mile Creek, and Bessey Creek. A characterization of the predevelopment St. Lucie watershed based on historical sources can be found in **Appendix E**.

Since the early 1900s, numerous water control facilities have been constructed to make this region suitable for agricultural, industrial, and residential use. The St. Lucie Canal (C-44) was constructed between 1916 and 1924 to provide an improved outlet for Lake Okeechobee floodwaters. From 1918 to 1919, the Fort Pierce Farms Drainage

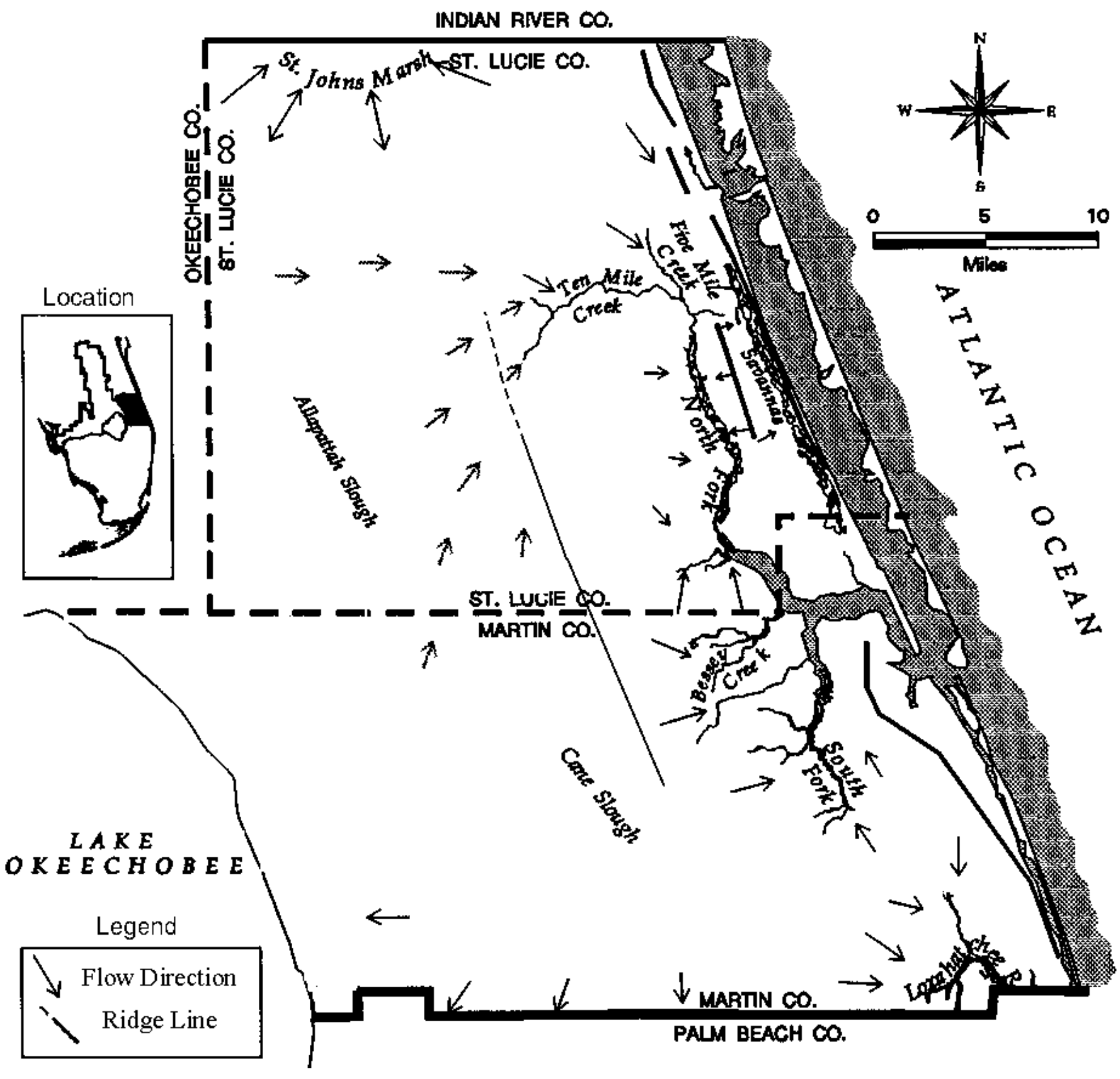


Figure 4. Historical Surface Water Drainage System in the St. Lucie Watershed

District and the North St. Lucie River Drainage District were formed to provide flood control and drainage for citrus production in east-central and northeastern St. Lucie County. The C-25 Canal (also known as Belcher Canal) provided a drainage outlet for the Fort Pierce Farms Drainage District, as well as a limited flood protection levee. The C-24 Canal (also known as the Diversion Canal) provided drainage and limited flood protection west of the North St. Lucie River Drainage District protection levee. The C-23 Canal provided water control in Allapattah Flats during the dry season. However, large areas continued to be under water for months at a time during the wet season.

Torrential rains and extensive flooding in South Florida in 1947 prompted the United States Congress to authorize the design and construction of the C&SF Project. The C&SF Project included construction of levees, canals, spillways, pump stations, and dams. The project incorporated the existing canals and provided increased outlet capacity for Lake Okeechobee by making improvements to the St. Lucie Canal.

MAJOR BASINS

St. Lucie Agricultural Area

The St. Lucie Agricultural Area is located in western St. Lucie County, eastern Okeechobee County, and northern Martin County. It includes all of the C-23, C-24, and C-25 basins, and part of the North Fork St. Lucie River basin (**Figure 5**).

The C-23, C-24, and C-25 Canals and control structures were improved under the C&SF Project. Their current functions are 1) to remove excess water from their respective basins, 2) to supply water during periods of low rainfall, and 3) to maintain ground water table elevations at the coastal structures to prevent saltwater intrusion.

The canals and control structures were designed to pass 30 percent of the Standard Project Flood and to meet irrigation delivery requirements for the basin. In this planning area, a Standard Project Flood is statistically equivalent to a 1-in-10 year, 72-hour storm event. Excess water may be discharged from C-25 to tidewater by way of the S-99 and S-50 structures, or to C-24 by way of the G-81 structure. Excess water in C-24 may be discharged to tidewater by way of S-49, to C-25 by way of G-81, or to C-23 by way of G-78. Excess water in C-23 may be discharged to tidewater by way of S-97 and S-48, or to C-24 by way of G-78 (SFWMD, 1993).

Flow in each of the C&SF Project canals is regulated by their respective control structures. For flood control and drainage, water elevations in the canal are set far enough below ground surface to provide slope in the secondary drainage systems. Water supply, on the other hand, requires that the water surface in the primary canal be maintained sufficiently high to prevent overdrainage. When flow in the canals is adequate, control structures are operated to maintain a headwater stage within a seasonally dependent range (**Table 1**).

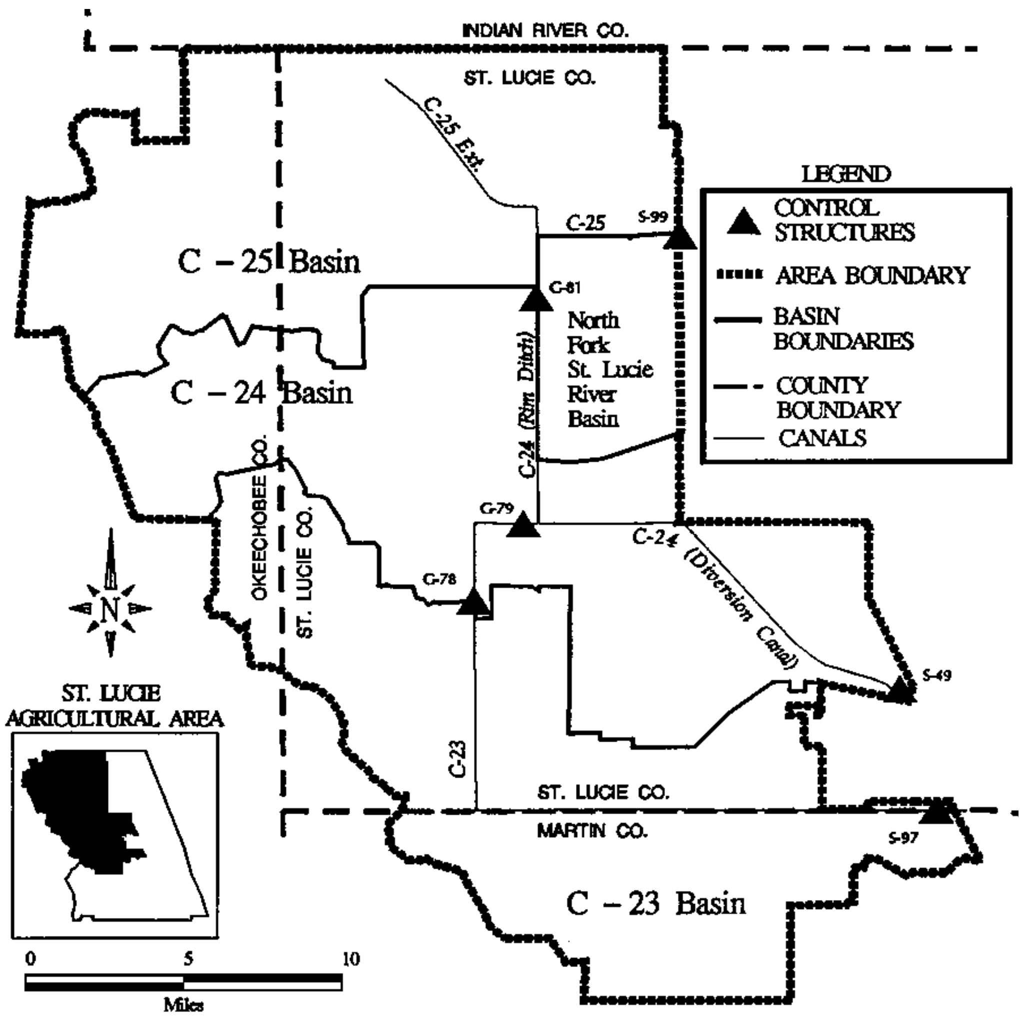


Figure 5. St. Lucie Agricultural Area Drainage Basins

Table 1. Optimal Headwater Stage for Project Canals

Canal	Structure	Headwater Stage (feet NGVD[a]) Wet Season[b]	Headwater Stage (feet NGVD[a]) Dry Season[c]
C-25	S-99	19.2 - 20.2	21.5 - 22.5
C-25	S-50	>12.0	>12.0
C-24	S-49	18.5 - 20.2	19.5 - 21.2
C-23	S-97	20.5 - 22.2	22.2 - 23.2
C-23	S-48	>8.0	>8.0

a. NGVD = National Geodetic Vertical Datum

b. Wet season is from May 15 to October 15 (Cooper and Ortel, 1988).

c. Dry season is from October 16 to May 14

Although the primary function of the C&SF Project was for flood control and drainage, the drainage network formed by the project canals and the secondary canals and ditches have become an important source of irrigation water and frost protection for agriculture. In general, rainfall, ground water inflow, and runoff replenish water stored in the canals.

Eastern St. Lucie Area

The Eastern St. Lucie Area includes most of the North Fork St. Lucie River basin and all of Basin 1. A map of the Eastern St. Lucie Area is presented in **Figure 6**.

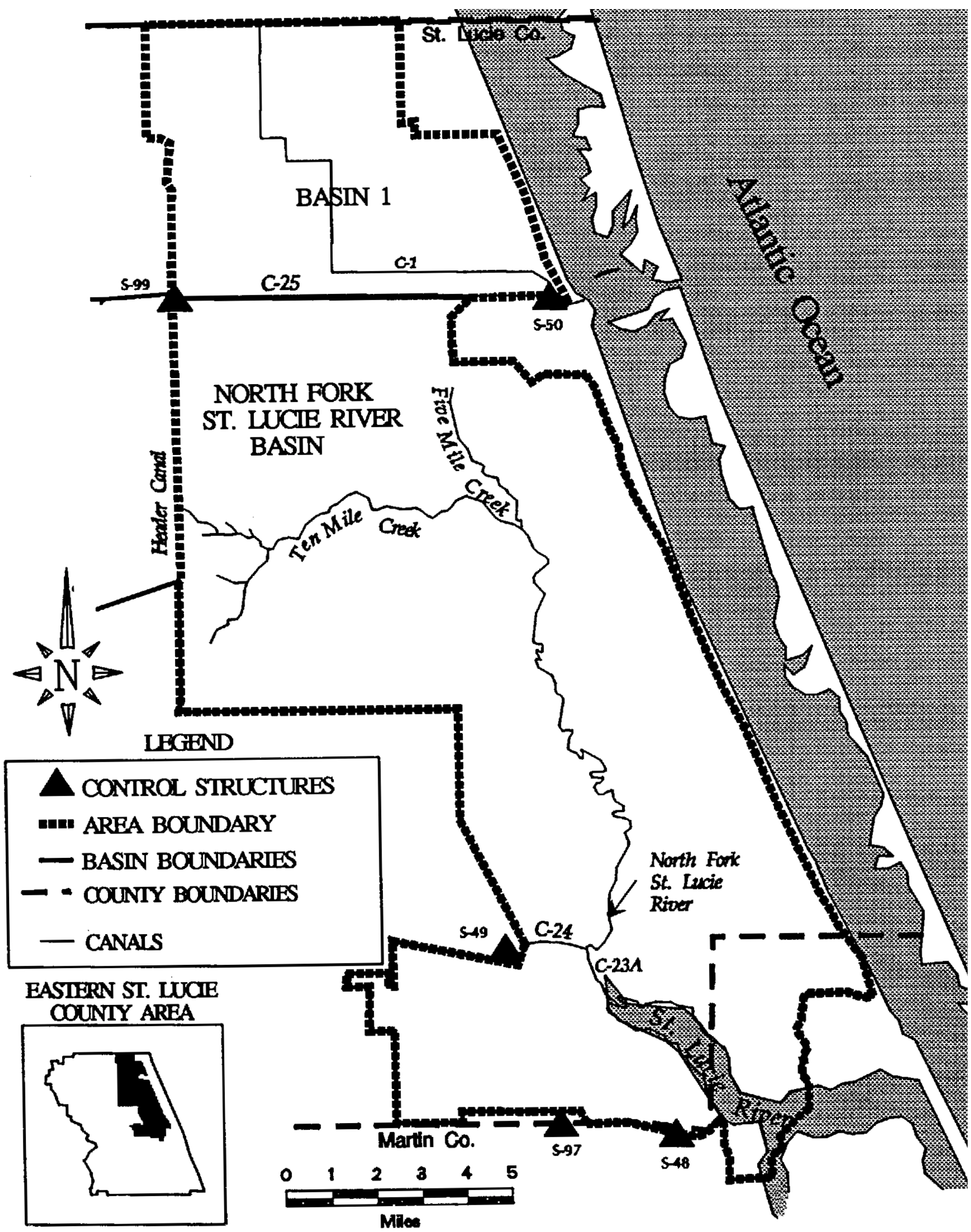


Figure 6. Eastern St. Lucie Area Drainage Basins

The North Fork of the St. Lucie River, is a natural watercourse although portions have been channelized. Ten Mile Creek and Five Mile Creek tributaries form its headwaters and, nineteen miles downstream, it joins the South Fork in discharging to the Atlantic Ocean via the St. Lucie Estuary and the Indian River Lagoon. Stages in the North Fork are tidally influenced throughout its length which varies from 100 feet wide upstream to over 4,000 feet wide downstream (Camp Dresser & Mckee, 1993). Portions of the North Fork are designated a state aquatic preserve flanked by a state buffer preserve on either side.

The North Fork of the St. Lucie River and the C-24 Canal serve as the primary drainage conveyances for southeastern and west-central St. Lucie County, and for small portions of eastern Okeechobee and northeastern Martin counties (Camp Dresser & McKee, 1993). Two C&SF Project canals, C-23A and C-24, are located in the North Fork St. Lucie River basin. C-23A is a short section of canal in the lower reach of the North Fork of the St. Lucie River. This canal passes discharges for both the North Fork and the C-24 Canal to the St. Lucie Estuary. A short reach of the C-24 Canal extends from the S-49 control structure to the North Fork, just north of C-23A. C-23A was designed to pass 30 percent of the Standard Project Flood from the North Fork St. Lucie River basin and from the C-24 basin.

Greater St. Lucie Canal Area

The Greater St. Lucie Canal Area covers most of Martin County (**Figure 6**). It can be subdivided in two categories: 1) the Canal Area which includes all of the C-44, S-153, and Tidal St. Lucie basins served by C&SF Project canals, and 2) Basins 4, 5, 6, and 8. Basin 8 drains out of the planning area and has little interaction with the rest of the Greater St. Lucie Canal Area. The Canal Area contains the only basin (C-44 basin) in the planning area that is hydrologically connected to Lake Okeechobee. Therefore, this section includes a discussion of the lake's regulation schedule.

Canal Area

The C&SF Project canal and control structures in the C-44 basin have five functions: 1) to provide drainage and flood protection for the C-44 basin; 2) to accept runoff from the S-153 basin and discharge this runoff to tidewater; 3) to discharge water from Lake Okeechobee to tidewater when the lake is over schedule; 4) to supply water to the C-44 basin during periods of low natural flow, and 5) to provide a navigable waterway from Lake Okeechobee to the Intracoastal Waterway. Excess water is discharged to tidewater by way of the S-80 structure and the C-44A Canal. Under certain conditions, excess water backflows to Lake Okeechobee by way of S-308. This happens about 50 percent of the time. Regulatory releases from Lake Okeechobee are made to the C-44 Canal by way of S-308. Water supply to the basin is made from Lake Okeechobee by way of S-308 and from local rainfall. Both S-80 and S-308 have navigation locks to pass boat traffic.

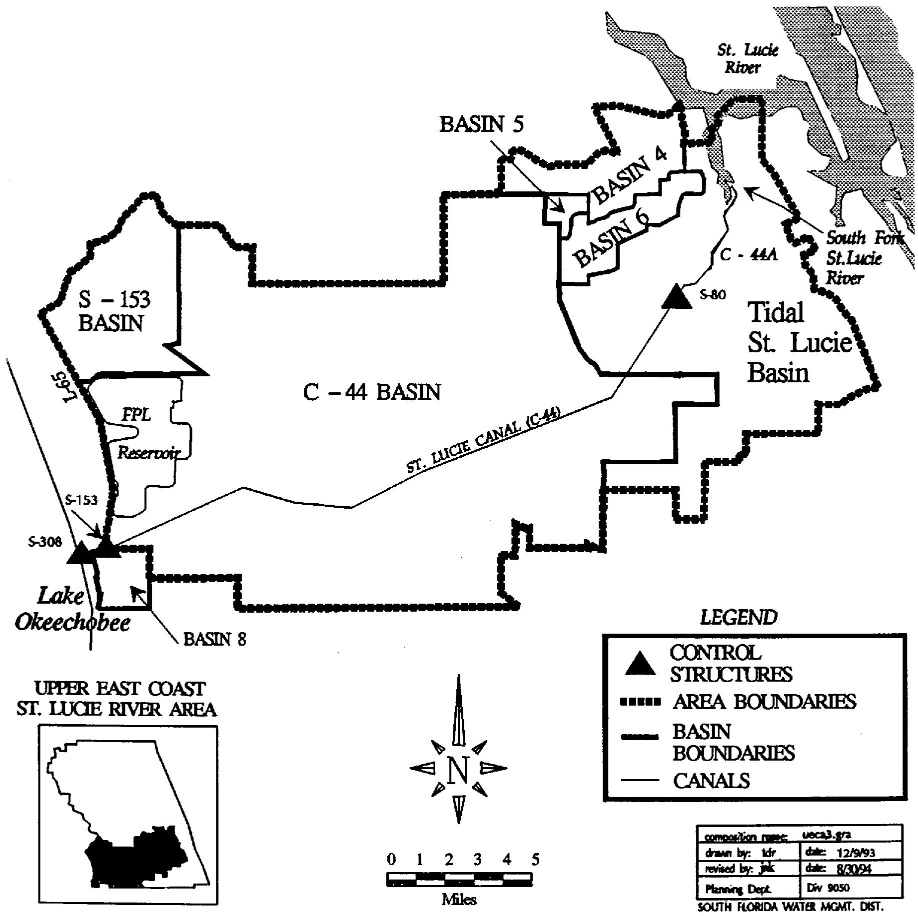


Figure 7. Greater St. Lucie Canal Area Drainage Basins

Lockages are performed "on demand" at S-80, except when water shortages have been declared or maintenance and repairs to the structure are taking place. Although, a water shortage plan has not been developed for S-80, the USACE will curtail lockages at the request of the District. Maintenance and repairs that result in stoppage of lockages are done on an as-needed basis, usually occurring every three to five years (SFWMD, 2000b). Each lockage at S-80 releases over 1.3 million gallons of water. The average number of lockages at S-80 varies monthly. Between 1987 and 1991, S-80 had an average of 15 lockages per day (SFWMD, 2000b).

The S-153 structure provides flood protection and drainage for the S-153 basin. Excess water in the basin is discharged to the C-44 Canal by way of the L-65 Borrow Canal. This 6,600-acre reservoir was originally part of the S-153 basin, but is now hydraulically connected to the C-44 Canal and is considered part of the C-44 basin. The S-153 control structure is operated to maintain an optimum stage of 18.8 feet National Geodetic Vertical Datum (NGVD).

The S-80 structure in the Tidal St. Lucie basin has three functions. These functions are 1) to accept flow from the C-44 Canal and to discharge those flows to tidewater in the St. Lucie River; 2) to provide a navigable waterway from the St. Lucie Canal to the Intracoastal Waterway; and 3) to provide drainage for portions of the Tidal St. Lucie basin.

The C-44 Canal and the S-80 Structure were designed to pass the Standard Project Flood from the C-44 basin and the S-153 basin and to pass regulatory discharges from Lake Okeechobee to tidewater. The S-308 and S-80 control structures are operated to maintain an optimum canal stage of 14.5 feet NGVD within the Tidal St. Lucie basin.

Contributing to surface drainage in the Tidal St. Lucie basin, the Old South Fork of the St. Lucie River is characterized by numerous oxbows winding through floodplain hammock and pine flatwoods for more than eight miles before connecting to the Okeechobee Waterway (C-44). It remains virtually unaltered from its historical watercourse although it has experienced hydrologic impacts due to surrounding land use classified as "predominantly well drained pasture/citrus groves connected to the river through a complex network of feeder canals" (Janicki et al., 1999).

Basins 4, 5, and 6

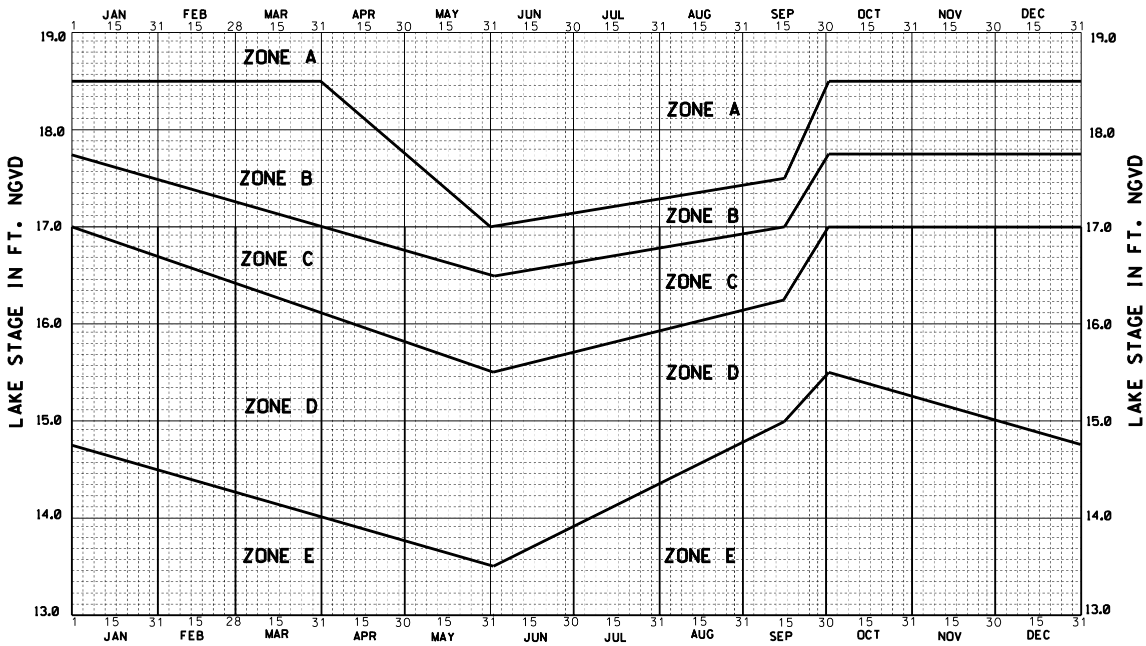
Basins 4 and 6 are drained by Bessey and Danforth Creeks, respectively. Bessey Creek discharges to the mouth of the C-23 Canal, which in turn empties into the St. Lucie River. Danforth Creek discharges to the South Fork of the St. Lucie River Estuary. Basin 5 is generally landlocked, with a poor hydraulic connection to Bessey Creek. Inadequate conveyance in the drainage systems in these basins has frequently resulted in areas of inundation in flood prone areas.

Lake Okeechobee

Lake Okeechobee is managed as a multipurpose freshwater resource in the C&SF Project. The primary tool for managing lake water levels is the regulation schedule. This schedule defines the ranges of water levels in which specific discharges are made to control excessive accumulation of water within the lake's levee system.

The schedule varies seasonally to best meet the objectives of the C&SF Project. A number of lake regulation schedules have been adopted since the construction of the C&SF Project (Trimble and Marban, 1988). In 1978, the USACE adopted the "15.5 – 17.5" schedule in which regulatory releases were made if stages in the lake exceeded 15.5 to 17.5 feet NGVD. A pulse release program was added in 1991 to reduce the likelihood of making large freshwater releases to the St. Lucie and Caloosahatchee River Estuaries. This schedule is commonly referred to as "Run 25".

Water releases from Lake Okeechobee to the estuaries currently depend on policies contained within the newly adopted Water Supply and Environmental (WSE) regulation schedule (**Figure 8**), which is structured to provide additional flexibility for discretionary releases of water from the lake for environmental benefits (USACE, 2000). An adaptive protocol process will be used to implement the operational flexibility of the WSE by providing additional guidance to operations for greater protection of Lake Okeechobee and downstream ecosystems while continuing to provide a reliable water supply for agricultural and urban areas that depend on the lake (SFWMD, 2002).



RELEASE THROUGH OUTLETS AS INDICATED

ZONE	AGRICULTURAL CANALS To WCAs (1,2)	CALOOSAHATCHEE RIVER AT S-77 (1,2,4)	ST. LUCIE CANAL AT S-80 (1,2,4)
A	PUMP MAXIMUM PRACTICABLE	UP TO MAXIMUM CAPACITY	UP TO MAXIMUM CAPACITY
B (3)	MAXIMUM PRACTICABLE RELEASES	NORMAL TO WET: UP TO 6500 CFS DRY: UP TO MAXIMUM PULSE RELEASE	NORMAL TO WET: UP TO 3500 CFS DRY: UP TO MAXIMUM PULSE RELEASE
C (3)	MAXIMUM PRACTICABLE RELEASES	WET: UP TO 4500 CFS NORMAL: UP TO MAXIMUM PULSE RELEASE DRY: NONE	WET: UP TO 2500 CFS NORMAL: UP TO MAXIMUM PULSE RELEASE DRY: NONE
D (3,5)	AS NEEDED TO MINIMIZE ADVERSE IMPACTS TO THE LITTORAL ZONE WHILE NOT ADVERSELY IMPACTING THE EVERGLADES. (SEE NOTE 5.)	VERY WET: UP TO MAXIMUM PULSE RELEASE OTHERWISE: NONE	VERY WET: UP TO MAXIMUM PULSE RELEASE OTHERWISE: NONE
E	NO REGULATORY DISCHARGE	NO REGULATORY DISCHARGE	NO REGULATORY DISCHARGE

NOTES:
(1) SUBJECT TO FIRST REMOVAL OF RUNOFF FROM DOWNSTREAM BASINS
(2) GUIDELINES FOR WET, DRY AND NORMAL CONDITIONS ARE BASED ON: 1) SELECTED CLIMATIC INDICES AND TROPICAL FORECASTS AND 2) PROJECTED INFLOW CONDITIONS. RELEASES ARE SUBJECT TO THE GUIDELINES IN THE WSE OPERATIONAL DECISION TREE, PARTS 1 AND 2.
(3) RELEASES THROUGH VARIOUS OUTLETS MAY BE MODIFIED TO MINIMIZE DAMAGES OR OBTAIN ADDITIONAL BENEFITS. CONSULTATION WITH EVERGLADES AND ESTUARINE BIOLOGISTS IS ENCOURAGED TO MINIMIZE ADVERSE EFFECTS TO DOWNSTREAM ECOSYSTEMS.
(4) PULSE RELEASES ARE MADE TO MINIMIZE ADVERSE IMPACTS TO THE ESTUARIES
(5) ONLY WHEN THE WCAs ARE BELOW THEIR RESPECTIVE SCHEDULES

CENTRAL AND SOUTHERN FLORIDA
INTERIM REGULATION SCHEDULE
LAKE OKEECHOBEE

DEPARTMENT OF THE ARMY, JACKSONVILLE DISTRICT
CORPS OF ENGINEERS, JACKSONVILLE, FLORIDA
DATED: 5 NOVEMBER 1999

WSE (WITH CLIMATE OUTLOOK)

Figure 8. The Interim WSE Schedule for Lake Okeechobee

Pulse releases prescribed in Zone D of the WSE are designed to lower lake stage with minimal impact to the estuary. The pulse releases consist of 10-day pulses that follow the release patterns that were designed to reflect the natural hydrology of storm water runoff. The release rate begins low on the first day and is increased to the highest release rate on the third day, followed by reduced flow rates for days seven through ten. After day ten the pattern of discharge is repeated until the lake level is sufficiently lowered. The pulse releases increase from Level 1 to Level 3 as shown in **Table 2**. The level of release is determined by the water stage in Lake Okeechobee.

Table 2. Pulse Release Schedules for the St. Lucie and Caloosahatchee River Estuaries and Their Effect on Lake Okeechobee Water Levels[a]

Day	Daily Discharge Rate (cubic feet per second)					
	St. Lucie Level I	**St. Lucie Level II**	**St. Lucie Level III**	**Caloosa.[b] Level I**	**Caloosa. Level II**	**Caloosa. Level III**
1	1,200	1,500	1,800	1,000	1,500	2,000
2	1,600	2,000	2,400	2,800	4,200	5,500
3	1,400	1,800	2,100	3,300	5,000	6,500
4	1,000	1,200	1,500	2,400	3,800	5,000
5	700	900	1,000	2,000	3,000	4,000
6	600	700	900	1,500	2,200	3,000
7	400	500	600	1,200	1,500	2,000
8	400	500	600	800	800	1,000
9	0	400	400	500	500	500
10	0	0	400	500	500	500
Acre-Feet per Pulse and Correlating Lake Level Fluctuations						
Acre-Feet per Pulse	14,476	18,839	23,201	31,728	45,609	59,490
Impact on Lake (feet)	0.03	0.04	0.05	0.07	0.10	0.13

a. Source: SFWMD, 1997
b. Caloosa. = Caloosahatchee

Although Lake Okeechobee is a potentially large source of water, it must supply many users within the region and is subject to regional rainfall conditions. These factors contribute to lake levels occasionally falling within the supply-side management zone (**Figure 9**). At low lake stages, water supply allocations are determined through procedures described in the *Lake Okeechobee Supply-Side Management Plan* (Hall, 1991), as modified in the *Lower East Coast Regional Water Supply Plan* (SFWMD 2000b). This plan states that the amount of water available for use during any period is a function of the anticipated rainfall, lake evaporation, and water demands for the balance of the dry season in relation to the amount of water currently in storage. If the projected lake stage falls below 10.5 feet NGVD at the end of the dry season, or below 13.0 feet NGVD at the end of the wet season, the Lake Okeechobee Supply-Side Management Plan (Hall, 1991) is implemented in conjunction with the District's Water Shortage Plan (Chapter 40E-21, F.A.C).

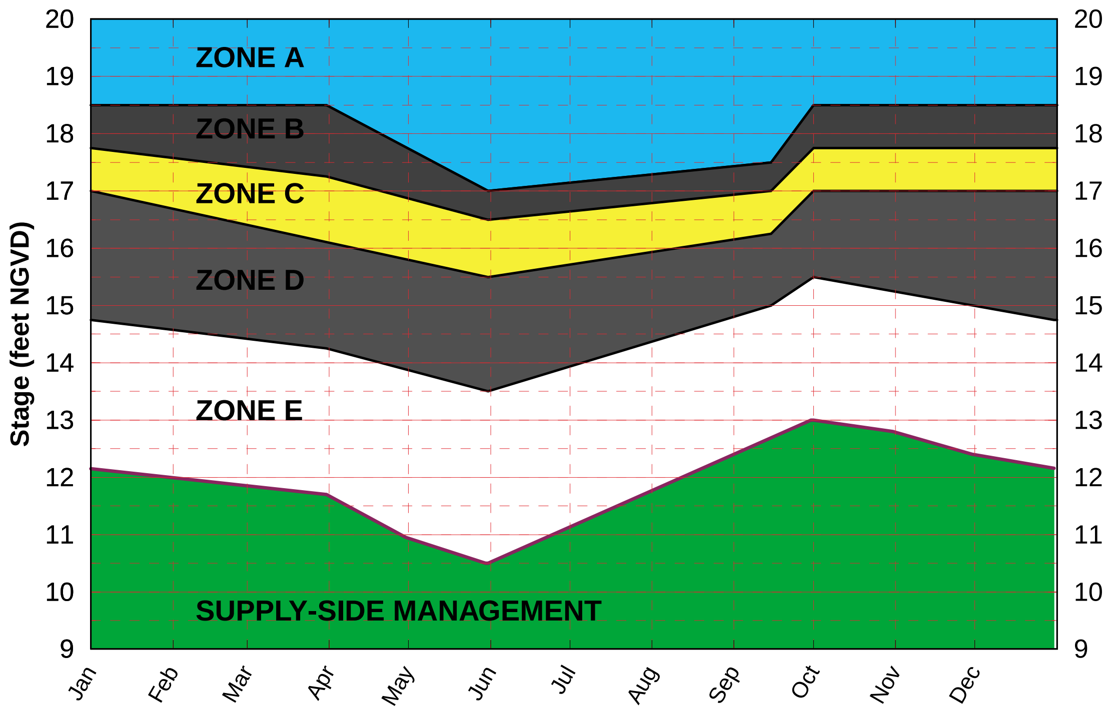


Figure 9. Management Zones for Lake Okeechobee, including Zones A through E Associated with the WSE Regulation Schedule and the Supply-Side Management Zone

St. Lucie Estuary

The estuary is divided into three major areas: the inner estuary, comprised of the North and South Forks; the midestuary, consisting of the area from the juncture of the North and South Forks to Hell Gate; and the outer estuary extending from Hell Gate to the St. Lucie Inlet (**Figure 10**). The main body of the North Fork is about four miles long, with a surface area of approximately 4.5 square miles and a volume of 468.7 by 106 cubic feet. The midestuary extends approximately 5 miles from the Roosevelt Bridge to Hell Gate and has an area and volume similar to the North Fork (4.7 square miles and 972.7 by 106 cubic feet) (Haunert and Startzman, 1985).

The bathymetry of the estuary has been mapped by the District (Morris, 1986). The center of the North Fork is approximately 10.0 feet deep; depth increases to 15.0 feet near its juncture with the South Fork. Depths within the South Fork also approach 10.0 feet within the channel, however, depths are generally much shallower near the Palm City Bridge. Maximum depths within the estuary are about 25.0 feet at sites near the Roosevelt Bridge and Hell Gate. Tidal influences in the North Fork reach 15 miles north of Stuart in Five-Mile Creek, and to a water control structure on Ten-Mile Creek just west of the Florida Turnpike at Gordy Road. Tidal influences in the South Fork extend about 8 miles south of Stuart to the St. Lucie Lock and Dam on the St. Lucie Canal. Tidal influence also extends into the extremes of the nearby Old South Fork tributary (Morris, 1987).

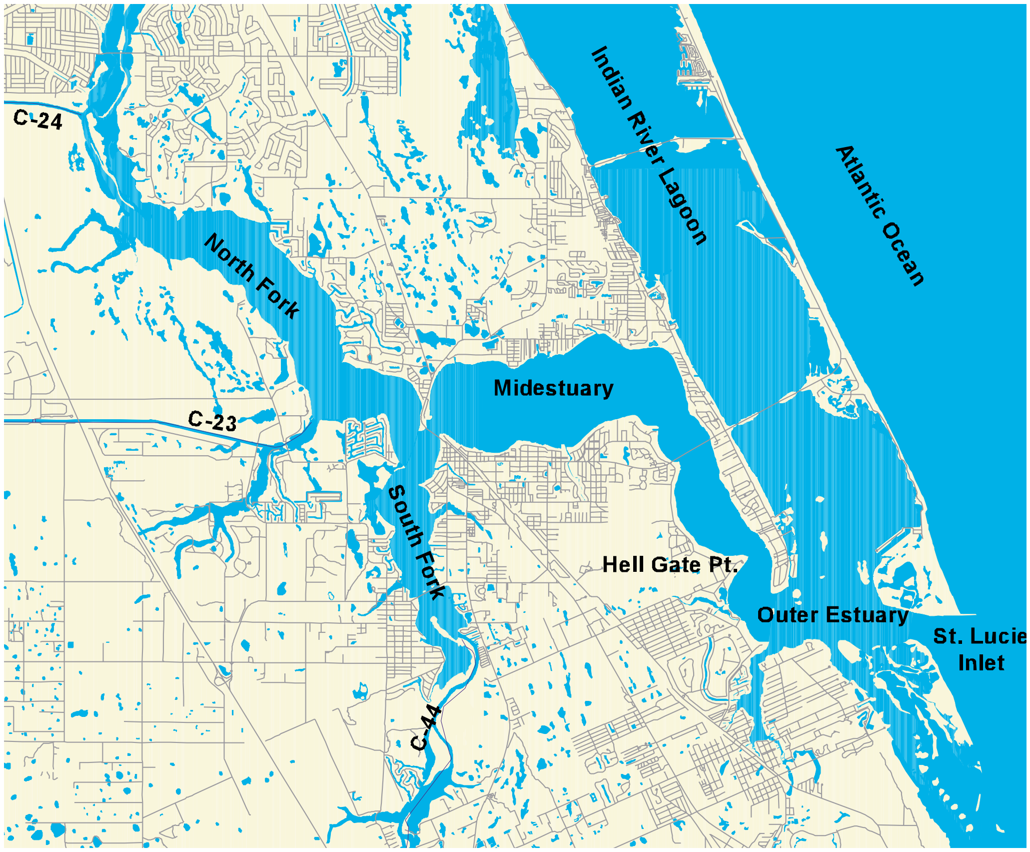


Figure 10. St. Lucie Estuary Hydrography

Surface sediment composition within the estuary has also been mapped by the District (Haunert, 1988). Sediment composition within the St. Lucie Estuary is influenced by hydrodynamics and is somewhat correlated to depth. Sand substrates, with little organic content, are found along the shallow shorelines of the estuary and in the St. Lucie Canal. This reflects the impacts of wave turbulence and rapid currents. Substrates comprised of mud and moderate quantities of sand are present in areas that are more typically low energy environments, but subjected to occasional high energy events. Mud substrates are found in low energy areas such as dredged areas and the deeper portions of the estuary. These mud sediments often contain high concentrations of organic materials.

The estuarine environment is sensitive to freshwater releases, and modification of the volume, distribution, circulation, or temporal patterns of freshwater discharges can place severe stress upon the entire ecosystem. Salinity patterns affect productivity, population distribution, community composition, predator-prey relationships, and food web structure in the inshore marine habitat. In many ways, salinity is the master ecological variable that controls important aspects of community structure and food web organization in coastal system (Myers and Ewel, 1990). Other aspects of water quality, such as turbidity, dissolved oxygen content, nutrient loads, and toxins, also affect functions of these systems (USFWS, 1990; Myers and Ewel, 1990).

Estuarine biota is well adapted to, and depends on, natural seasonal changes in salinity. The temporary storage and concurrent decrease in velocity of floodwaters within upstream wetlands aid in controlling the timing, duration, and quantity of freshwater flows into the estuary. Upstream wetlands and their associated ground water systems contribute to base flow discharges into the estuaries, providing favorable salinities for estuarine biota. Maintenance of these base flows supports the propagation of many commercially important fish species, such as snook, tarpon, sea trout, and redfish.

During the wet season, upstream wetlands provide pulses of organic detritus, that are exported downstream to the brackish water zone. These materials are an important link in the estuarine food chain.

LAND USE

The St. Lucie watershed is predominantly agricultural, especially in St. Lucie County. Urban land use is primarily located in the coastal portions of Martin and St. Lucie Counties. The highest percentage of wetlands is in Martin County (**Table 3**).

Based on local government comprehensive plans, urbanization is anticipated to increase in both Martin and St. Lucie Counties. Agriculture has been the predominant land use in both counties and is projected to remain so in the future. However, the percentage of agricultural land use is projected to decrease as a result of urban encroachment. The most significant change in land use is the doubling of urban acreage, which reflects population growth in these two counties.

Table 3. Acreages and Percentages of Land Use by County[a]

Land Use	Martin County		St. Lucie County	
	Acres	Percent[b]	Acres	Percent[b]
Agriculture	137,361	40	191,081	50
Urban and Transportation	50,416	15	72,500	19
Wetlands	54,116	16	33,374	9
Upland Forest	64,201	19	38,880	10
Rangeland	5,503	2	8,129	2
Barren	2,075	1	316	0
Water	26,706	8	40,612	10
Total	**340,378**	**100**	**384,892**	**100**

a. Source: SFWMD Florida Land Use/Land Cover geographical information system (GIS) database, 1995

b. Percentages rounded to the nearest tenth

WATER RESOURCES

Surface Water Inflow and Outflow

Essentially all surface water inflows and outflows in the planning area are derived from rainfall. The exception to this is the St. Lucie Canal (C-44), which also receives water from Lake Okeechobee. In addition, most of the flows and stages in the regions' canals are regulated for water use and flood protection. The amount of stored water is of critical importance to both the natural ecosystems and the developed areas in the region. Management of surface water storage capacity involves balancing two conflicting conditions. When little water is in storage, drought conditions may occur during periods of deficient rainfall. Conversely, when storage is at capacity, flooding may occur due to excessive rainfall, especially during the wet season.

Surface Water-Ground Water Relationships

Sections of two vast aquifer systems, the Surficial Aquifer System and the Floridan Aquifer System, underlie the St. Lucie watershed. Ground water inflows from outside the area form an insignificant portion of recharge to the Surficial Aquifer System. Rainfall is the main source of recharge to this system, and because of this, long-term utilization of this source must be governed by local and regional recharge rates. The Floridan Aquifer System, on the other hand, receives most of its recharge from outside of the St. Lucie watershed.

The construction and operation of surface water management systems affect the quantity and distribution of recharge to the Surficial Aquifer System. Although a major source of water supply, in terms of their interaction with ground water, surface water management systems within the planning area function primarily as aquifer drains. Adams (1992) estimated that 19 percent of ground water flow in Martin County is discharged into surface water bodies, while only one percent of aquifer recharge is derived from surface water sources. Surface water management systems also impact aquifer recharge by diverting rainfall from an area before it has time to percolate down to the water table. Once diverted, this water may contribute to aquifer recharge elsewhere in the system, supply a downstream consumptive use, or it may be lost to evapotranspiration or discharged to tide.

Water Supply

Water for urban and agricultural uses in the region comes from three main sources: the Floridan Aquifer System, the Surficial Aquifer System, and surface water. Surface water is used primarily for agricultural irrigation, with the Floridan Aquifer System used as a backup source during periods of low rainfall. Although the Floridan Aquifer System is not hydraulically connected to surface water within the planning area, Floridan Aquifer System water is usually diluted with surface water to achieve an acceptable quality for agricultural irrigation.

The Surficial Aquifer System is the principal source for public water supply and urban irrigation. However, as the population in the planning area increases, the urban areas are anticipated to increase their use of the Floridan Aquifer System as a source of drinking water (SFWMD, 1998a).

Nonenvironmental water use assessments for 1990 and projections for 2010 were made for five categories of water use. The category of *public water supply* refers to all potable water supplied by regional water treatment facilities with pumpage greater than 500,000 gallons per day (GPD) to all types of customers, not just residential. The other four categories of water use are self-supplied. *Commercial and industrial self-supplied* refers to operations using over 100,000 GPD. *Recreation self-supplied* includes landscape and golf course irrigation demand. The landscape subcategory includes water used for parks, cemeteries, and other irrigation applications greater than 100,000 GPD. The golf course subcategory includes those operations not supplied by a public water supply or regional reuse facility. *Residential self-supplied* is used to designate only those households whose primary source of water is private wells. *Agriculture self-supplied* includes water used to irrigate all crops, and for cattle watering (SFWMD, 1998a).

From 1990 to 2010, the total water demand is projected to increase by 34 percent (**Table 4**). Public water supply has the largest projected increase of 143 percent. However, agricultural water demand is projected to remain the single largest category of use. In 1990, agriculture accounted for 84 percent of the total demand.

Table 4. Overall Water Demands for 1990 and 2010[a]

Category	Estimated Demands 1990 (MGY[b])	Projected Demands 2010 (MGY)	Percent Change 1990-2010
Public Water Supply	9,607	23,371	143
Commercial and Industrial Self-Supplied	850	1,570	85
Recreation Self-Supplied	7,233	13,910	92
Residential Self Supplied	6,398	6,876	7
Agriculture Self-Supplied	130,191	160,528	23
Total	**154,279**	**206,255**	**34**

a. Source: SFWMD, 1998a

b. MGY = million gallons per year

Agricultural drainage and residential development have extensively modified the watershed of the entire St. Lucie Estuary. Major effects of these anthropogenic changes in the landscape and water management practices are increased drainage manifested by a lowered ground water table and dramatic changes in how storm water runoff is introduced to the estuary. Typically, when a watershed is highly drained like the St. Lucie Estuary watershed, all three runoff factors (quality, quantity, and timing) are negatively affected. From a yearly cycle perspective, the quantity of water drained to the estuary is increased, the water quality is degraded and the seasonal distribution of runoff is altered such that dry season flows are of lesser magnitude and less frequent and wet season flows are of greater magnitude and more frequent. From a short-term perspective, these three factors are all negatively affected due to the accelerated rate of runoff from the watershed. The vast majority of runoff occurs within the first three days instead of over an extended period of time.

Urban Water Supply Demands

Urban water demands include 1) public water supply provided by utilities, 2) residential self-supplied, 3) commercial and industrial self-supplied, and 4) recreation self-supplied. In the Upper East Coast Planning Area, public water supply was the largest component (40 percent) of urban water demand in 1990, followed by recreation self-supplied (30 percent), residential self-supplied (27 percent), and commercial and industrial self-supplied (4 percent). Urban water demand in 1990 was estimated to be about 24 billion gallons per year and is projected to increase to almost 46 billion gallons per year in 2010 (SFWMD, 1998a).

The driving force behind urban demand is population. Population numbers for 1990 were taken from the United States Census. Population projections for 2010 were obtained from the county and local government comprehensive plans, derived from the portions of the counties within the planning area (**Table 5**), and used to develop urban demand projections. The total population of the planning area for 1990 is projected to increase 77 percent in 2010 (SFWMD, 1998a).

Table 5. Estimated and Projected Population in the Upper East Coast Planning Area for 1990 and 2010, respectively[a]

Region	Estimated Population 1990			Projected Population 2010		
	Total	Public Water Supply	Residential Self-Supplied	Total	Public Water Supply	Residential Self-Supplied
St. Lucie Area	150,171	86,808	63,364	290,100	221,320	68,780
Martin Area	100,900	54,935	45,965	154,200	101,520	52,680
Okeechobee Area	1,015	0	1,015	1,625	0	1,625
Total Planning Area	252,086	141,743	110,344	445,925	322,840	123,085

a. Source: Local Government Comprehensive Plans and United States Bureau of the Census, 1992

Agricultural Water Supply Demand

Agricultural water demand was estimated for 1990 to be approximately 130 billion gallons. Citrus was by far the largest agricultural water demand (82 percent) and is followed by sugarcane (11 percent). Vegetables, sod, cut flowers, and ornamental nurseries combined account for about three percent of the total agricultural demand. The combined water demand for cattle watering and irrigation of improved pasture also account for about three percent (SFWMD, 1998a). Subsequent analyses prepared while updating the Upper East Coast Water Supply Plan (due in 2003) indicate that citrus production is projected to gradually decline and level off, resulting in a 116 million gallons per day reduction in water needs (SFWMD, 2001a).

Agricultural water demand is forecast to increase by 23 percent to 161 billion gallons per year in 2010. Approximately 95 percent of the agricultural water demand is anticipated to be for citrus (85 percent) and sugarcane (10 percent). Vegetables, sod, and ornamental nurseries are each projected to represent about one percent of the total 2010 agricultural water demand (SFWMD, 1998a).

WATER QUALITY

A critical relationship exists between water quality and human activity, including the use of land for urban, agricultural, and industrial purposes and withdrawal of water for supply. Drainage, runoff, and seepage from developed lands carry sediments, fertilizers, and pollutants into surface and ground waters. Increased withdrawals and the by-products of treatment may increase the concentrations of impurities in the remaining water. Other human activities such as waste disposal and chemical spillage have the potential of degrading ground and surface water systems.

Modifications to the watershed have caused increased inflows to the St. Lucie Estuary during the last 100 years. Construction of canals, land development, extreme salinity fluctuations, and corresponding increases in sediment and chemical loadings have contributed to major changes in the structure of plant and animal communities within the estuary, resulting in loss of important features such as shoreline vegetation, sea grasses, and oysters. Phillips (1961) described the marine plants in the St. Lucie Estuary. At the time, mangroves were abundant in the North and South Forks and sea grasses, although stressed, were still found in many areas of the estuary. Today, the presence of sea grasses is severely limited and ephemeral and mangroves are sparsely distributed. Oyster populations in the estuary are virtually nonexistent due to the continual exposure to low salinities and lack of suitable substrate (clean hard objects) for larval recolonization (Haunert and Startzman, 1980, 1985).

Lake Okeechobee and C-44 Canal Discharges

Major regulatory discharges from the C-44 Canal have been documented to adversely impact the St. Lucie Estuary by depressing the salinity range far below the normal range, and by transporting large quantities of suspended materials into the estuary. Sedimentation problems in relation to C-44 discharges were recognized as early as the 1950s (Gunter and Hall, 1963). While current monthly average flows from the watershed to the St. Lucie Estuary seldom exceed 2,500 cubic feet per second (cfs), regulatory releases from the C-44 alone have produced flows in excess of 7,000 cfs. The quantity of suspended solid material passing through the S-80 structure reached a peak of 8,000 tons a day when daily discharges neared 7,000 cfs in 1983. Much of this material passes through the estuary and into the Indian River Lagoon or the Atlantic Ocean (Haunert, 1988). It was recognized then that these discharges transported sand as well as very fine, organic-rich suspended material to the estuary. Recent studies (FDEP, 2001) indicate runoff from the basin and water from the lake may also periodically contain significant concentrations of nitrogen and phosphorus.

A regulatory discharge from Lake Okeechobee that occurred as part of the managed recession in April 2000 resulted in a rapid drop of salinity and high levels of turbidity. More than 16 tons of phosphorus were discharged during this event. Oysters that were placed in the South Fork Estuary to monitor biological effects of the discharge were killed, whereas similar oysters placed in the North Fork Estuary, Middle Estuary, and Indian River showed no mortality (FDEP, 2000).

Inflow Water Quality from Other Tributaries

Graves and Strom (1992) concluded that the major canals (C-23, C-24, and C-44) provide the majority of nitrogen, phosphorus, and suspended solids that are discharged into the estuary. Sediments and water in these canals also periodically contain sufficiently high levels of certain heavy metals and pesticides to be toxic to fishes and aquatic invertebrates. Remaining "natural" waterways that pass through urban or residential landscapes may have a wider range of nutrient and dissolved oxygen concentrations, but are less of a problem in the sense that they contribute much less flow and material to the estuary.

Algal blooms that occurred during 1999 in the St. Lucie Estuary were linked to runoff from local watersheds rather than discharge from Lake Okeechobee. Samples indicated that high levels of nitrogen and phosphorus, as well as copper and the pesticide simazine were present in runoff from tributary basins (FDEP, 1999a). Additional sampling indicated that arsenic and ethion were present in high concentrations in some areas associated with runoff from a golf course and farms. High levels of nitrogen and phosphorus occurred in runoff from residential areas in Fort Pierce and Port St. Lucie (FDEP, 1999b).

Sediment Quality

In 1969, the United States Geological Survey (USGS) characterized suspended sediments carried by the C-23 and C-24 Canals. It was estimated that, in 1969, these canals discharged 4,500 and 9,000 tons of sediment, respectively, to the St. Lucie Estuary. These have also been characterized as very fine organic sediments (Pitt, 1972). Land use in the watersheds of these tributaries is primarily agricultural. The C-23 basin also contains a substantial proportion of upland forest, wetlands, range, and open water. Occasional high levels of phosphorus and nitrogen occur. Ethion, copper, and lead are present in high concentrations in the sediments (FDEP, 2000b, 2000c).

In 1984, the SFWMD provided funding to the University of South Florida to study sedimentation within the St. Lucie Estuary. High sedimentation rates were estimated at 0.5

to 1.0 centimeters (cm) per year for the past 100 years based upon historical bathymetry, and 1.0 to 2.6 cm per year based upon a radioactive dating technique (Davis and Schrader, 1984; Schrader, 1984). Recently deposited sediments were characterized as a black, organic-rich muck covered by a flocculent layer. The flocculent layer varied in thickness, with an average depth of 1.6 feet (Schrader, 1984).

Findings from a comprehensive characterization of the St. Lucie Estuary surface sediments (Haunert, 1988) indicate that portions of the St. Lucie Estuary contain extremely high concentrations of organic material (muck) in sediments when compared to other similar estuarine systems. These organics, contributed from upland sources and biological die-off within the estuary, produce anaerobic conditions and toxic hydrogen sulfide within the estuary. Samples in the North Fork contain as much as 64 percent organics by dry weight. South Fork values are as high as 49 percent by dry weight. In the middle estuary, an area of enriched sediments (20 to 30 percent) is found near the former discharge site of the Stuart Wastewater Treatment Plant (Haunert, 1988). More recent studies have confirmed the presence of a large layer of flocculent ooze within deeper portions of the St. Lucie Estuary (Schropp et al., 1994).

Water Quality Impacts of MFLs

Studies of the St. Lucie Estuary by Chamberlain and Hayward (1996) concluded that water quality in the estuary is dramatically impacted by the high flow rates that occur during severe storm events and regulatory discharges and that more stable, lower flows will improve water quality. It is important to quantify the water quality characteristics of lower inflows to determine potential impacts of the proposed MFL criteria. Freshwater inflow to estuaries brings with it nutrients, dissolved and particulate organic matter, inorganic particles including silts, clays, and sand. The effects of altering these inputs should be considered. A water quality model is an appropriate tool to perform such an analysis. In particular, the water quality model can be designed to address the following questions related to MFLs:

- What are the nutrient loads under the minimum flows?
- How does the St. Lucie Estuary respond, in terms of algal growth and dissolved oxygen, to a prolonged period of minimum flows?
- Under low inflow conditions, salinity levels may be well mixed within the water column, yet further salinity intrusion will take place. On the other hand, the water column may become more stratified under high inflows. Do these changes intensify the dissolved oxygen stratification in the water column?
- What is the role of sediments in contributing to benthic oxygen demand and nutrient fluxes when the bottom layer of the water in the estuary becomes anaerobic?

It should be pointed out that several water segments in the St. Lucie River basin are listed in the 303(d) list for water quality impairment as defined under Section 99-223, F.S., and the FDEP Impaired Water Rule (Chapter 62-303, F.A.C.): St. Lucie Estuary, St.

Lucie Canal, and the South Fork of the St. Lucie River. Modeling studies in the St. Lucie Estuary were conducted to develop total maximum daily loads (TMDLs) should be consulted as a basis for refining the St. Lucie Estuary MFLs in the future. Further discussion of the effects of freshwater discharge on salinity, nutrients, organic materials, and sediments is provided in **Chapter 3**.

NATURAL SYSTEMS

Wetlands

Wetlands are present throughout the region as shown in **Figure 11**. Although numerous man-made impacts have altered the landscape, significant wetland systems remain in the region.

Martin County

The area now known as the Allapattah Flats (**Figure 4**) was historically a series of sloughs that, during wet years, flowed from St. Lucie County southeast into Martin County and into the St. Lucie River (**Appendix D**). During average and dry years, the western wetlands generated no runoff. Highways, railroads, and drainage projects (FPL, 1988) have modified this drainage pattern. Currently, a series of isolated creeks, ponds, hammocks, sloughs, and wet prairies exist within the footprint of the original Allapattah Slough (MCGMD, 1990).

Another large wetland system, Cane Slough (**Figure 4**), is located immediately west of Interstate 95. This slough flows from the northwest to the southeast and is a recharge area for the headwaters of the St. Lucie River. A channelized connection exists between Cane Slough and the St. Lucie Canal. As a result of channelization and dikes, Cane Slough now consists of isolated cypress areas, ponds, and wet prairies.

The DuPuis Reserve and the Pal Mar Tract (**Figure 11**) also contain significant wetland systems. The 21,875-acre DuPuis Reserve is located in southwestern Martin County and northwestern Palm Beach County. This site contains numerous ponds, wet prairies, cypress domes, and remnant Everglades marsh. Management efforts are being directed toward improving wildlife habitat by restoring the hydrology of marshes and wet prairies and implementing prescribed burning and melaleuca control programs. The 37,314-acre Pal Mar Tract is located in Martin and Palm Beach counties. This tract is in the process of being acquired through the Save Our Rivers Program, the Conservation and Recreation Lands Program, and Martin and Palm Beach County acquisition programs. Pal Mar wetlands are primarily wet prairie ponds interspersed within a pine flatwood community. Despite some ditching, these wetlands are generally in good condition. The Pal Mar Save Our Rivers acquisition boundary includes a wildlife corridor that would connect Jonathan Dickinson State Park, Pal Mar, Corbett Wildlife Management Area (in Palm Beach County), and the DuPuis Reserve.

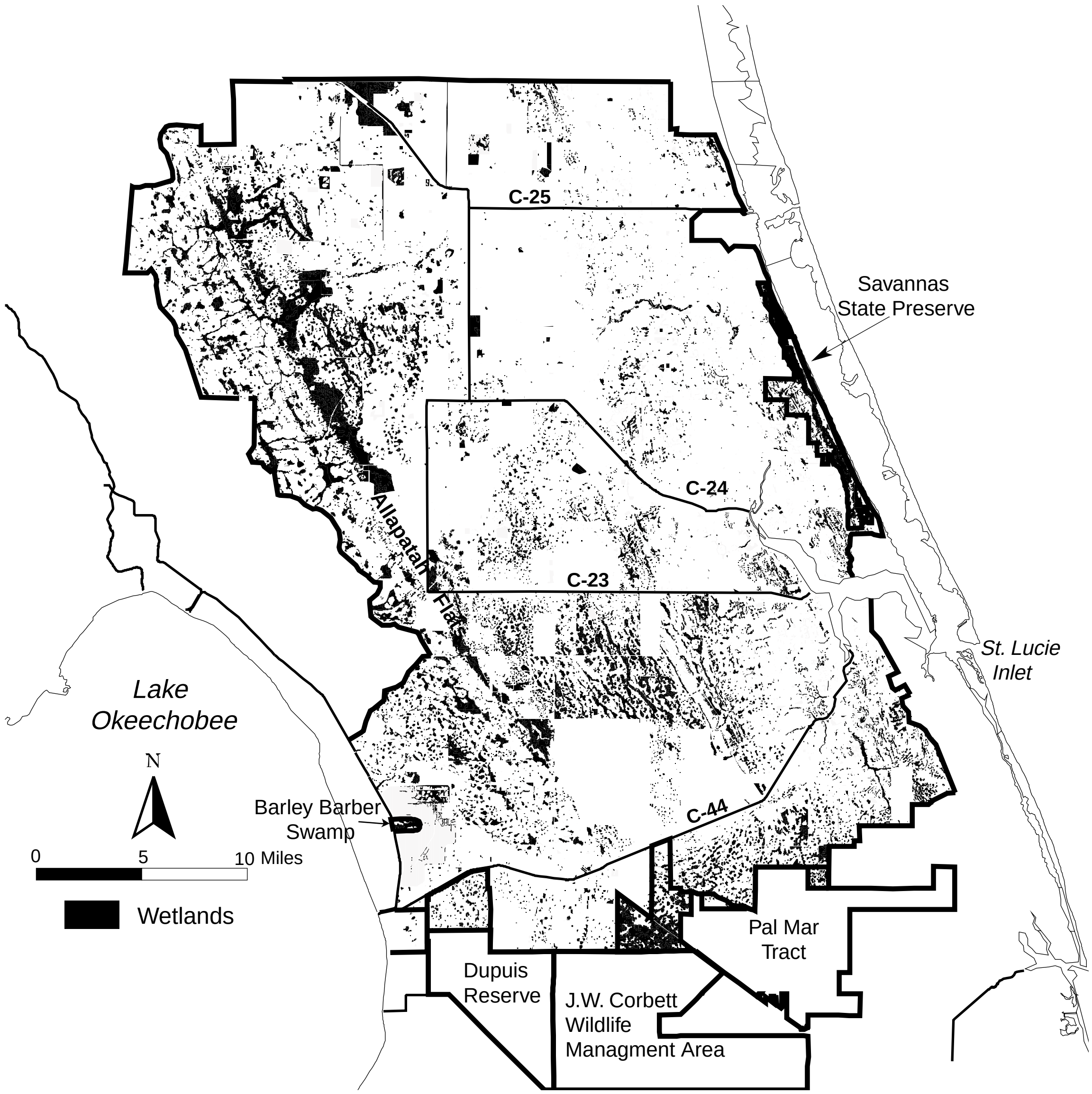


Figure 11. St. Lucie Watershed Wetlands and Natural Areas

St. Lucie County

Emergent shrub and forested wetlands once covered much of St. Lucie County. However, many of these wetlands have been extensively drained to support agricultural and urban development. The few large remaining inland wetland systems include the Savannas; wetlands associated with Five Mile, Ten Mile, Cow, Cypress, and Van Swearingen Creeks; remnant portions of St. Johns Marsh; and the floodplain of the North Fork of the St. Lucie River (**Figure 4**).

The Savannas is a freshwater wetland system located west of the Atlantic Coastal Ridge. It is one of the most endangered natural systems in the region. Historically, the

Savannas formed a continuous system that stretched the length of the county. It was later interrupted by the drainage and development of Fort Pierce. The State of Florida under the Conservation and Recreation Lands Program (**Figure 11**) has purchased much of the system south of Fort Pierce.

Uplands

Upland plant communities in the region include pine flatwoods, scrubby flatwoods, sand pine scrub, xeric oak, and hardwood hammocks. Uplands serve as recharge areas, absorbing rainfall into soils where it is used by plants or stored underground within the aquifer. Ground water storage in upland areas reduces runoff during extreme rainfall events, while plant cover reduces erosion and absorbs nutrients and other pollutants that might be generated during a storm. Upland communities, particularly pine flatwoods and sand pine scrub, are seriously threatened by development.

Pine flatwoods are the dominant upland habitat within the region. These plant associations are characterized by low, flat topography, and poorly drained, acidic, sandy soils. Under natural conditions, fire maintains flatwoods as a stable plant association. However, when drainage improvements and construction of roads and other fire barriers alter the natural frequency of fire, flatwoods can succeed to other community types. The nature of this succession depends on soil characteristics, hydrology, available seed sources, or other local conditions (Myers and Ewel, 1990).

Xeric sand pine scrub communities, although not as diverse as pine flatwood communities, contain more endangered and threatened plants and animals than any other South Florida habitat. Most of the sand pine scrub in the area is associated with the one to three-mile wide ancient dunes that line along the eastern edge of the coastal ridge in Martin and St. Lucie counties.

St. Lucie Estuary

Conceptual Model Approach

Participants in a series of interagency workshops held from August 1999 to November 2000 developed the framework for a conceptual model of the St. Lucie Estuary and Indian River Lagoon. This model was developed and structured to support the applied science strategy currently being implemented in the restoration, coordination, and verification (RECOVER) monitoring and assessment process that is a major component of the Comprehensive Everglades Restoration Plan (CERP). The St. Lucie Estuary/Indian River Lagoon Conceptual Model (**Appendix A**) identifies the major stressors in the St. Lucie River and Estuary watershed, the ecological and biological effects they have on the ecosystem, and the attributes in the natural systems that are the best indicators of the changes that have occurred as a result of the stressors (USACE and SFWMD, 1999). The basic features of this model are represented in **Figure 12**. The elements of this model that are related to development of MFLs are primarily linked to water management practices (as an external driver) as these result in altered hydrology and altered estuarine salinity

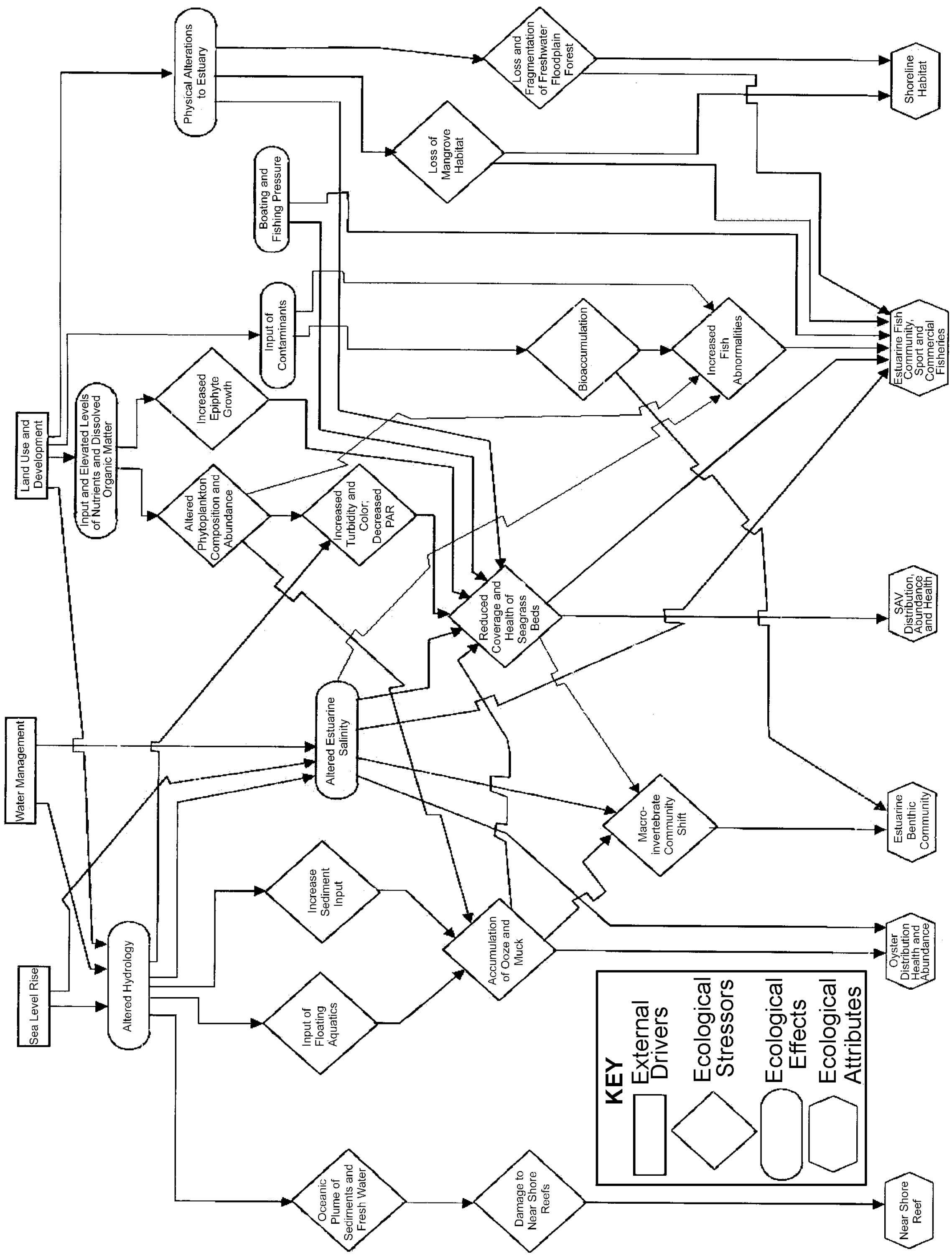


Figure 12. St. Lucie Estuary/Indian River Lagoon Conceptual Model

(ecological effects). According to the model, these effects, in turn, induce stress by causing increased turbidity, damage to sea grasses, shifts in macro invertebrate communities and accumulation of ooze and muck sediments. Changes in ecological attributes, such as oysters, benthic communities, aquatic vegetation, and fishes, reflect impacts to the estuary as noted in the following sections that are summarized from **Appendix A**.

Oyster Distribution Health and Abundance

Oysters and other bivalves, such as mussels and *Rangia,* are sensitive to salinity and siltation in the St. Lucie Estuary. Under natural conditions, oyster reefs can be very large and provide extensive attachment area for oyster spat and numerous associated species such as mussels, tunicates, bryozoans, and barnacles (Woodward-Clyde, 1998). Oysters have been documented in the past as abundant in the estuary and lagoon. Presently, their distribution is limited to approximately 200 acres from the estimated historic coverage of 1,400 acres (Woodward-Clyde, 1998). Generally adult oysters require salinity levels above 3 ppt, thrive at 12 to 20 ppt, and are adversely affected by diseases, predators, and algal blooms at seawater salinity conditions (Quick and Mackin, 1971; Mackin, 1962).

Estuarine Benthic Communities

Benthic macro invertebrate communities in the St. Lucie Estuary are sensitive to bottom type, water quality, and salinity fluctuations. A decline in diversity of benthic organisms and the spread of pollution-tolerant macro invertebrates is often an indicator of deteriorated water quality in an estuary. Haunert and Startzman (1985) found that fluctuations between periods of high and low discharge cause alternating shifts between estuarine and freshwater species. An overall reduction of 44 percent of the benthic macro invertebrates occurred during a three-week experimental freshwater release of 2,500 cfs. The greatest change in benthic species composition occurred in the newly created oligohaline zone (0.5 to 5 ppt). In this zone, the freshwater midge (*Chironomus crassicaudatus*) increased dramatically. Additionally, six freshwater species were introduced and at least four estuarine species were lost from the shifted oligohaline zone (Haunert and Startzman, 1985).

Submerged Aquatic Vegetation

Submerged sea grasses and freshwater macrophytes provide habitat and nursery grounds for many fish and invertebrate communities (Gilmore, 1977, 1988; Gilmore et al., 1981, 1983; Stoner, 1983) and they are food sources for trophically and commercially important organisms (Dawes et al., 1995; Virnstein and Cairns, 1986). Other important roles of submerged aquatic vegetation include benthic-based primary productivity and sediment stabilization (Stoner 1983; Virnstein et al., 1983; Gilmore, 1987; Woodward-Clyde, 1998). In a field study conducted by Woodward-Clyde in 1997, the only significant submerged aquatic vegetation beds in the St. Lucie Estuary occurred in the lower estuary near Hell Gate Point. Shoal grass *(Halodule wrightii)* was the dominant species throughout most of this area, with Johnson's sea grass (*Halophila johnsonii)* as the secondary species. The only other documented occurrences of submerged aquatic vegetation during that study was a very small amount of widgeon grass *(Ruppia maritima)*, wild celery (*Vallisneria americana)*, and common water nymph (*Najas guadalupensis*) in the South Fork of the estuary as well as a small area of widgeon grass in the North Fork.

All species of submerged aquatic vegetation respond negatively to rapidly changing salinity. Decreased light penetration that results from silt, turbidity, color, and phytoplankton blooms further stresses these plant communities. Sea grass loss negatively impacts fish and invertebrate communities. Also, it results in the destabilization of sediments and a shift in primary productivity from benthic macrophytes to phytoplankton, which provide negative feedback to further diminish sea grass beds (Woodward-Clyde, 1998).

Estuarine Fish Communities/Sport and Commercial Fisheries

The St. Lucie Estuary provides habitats and nursery grounds for a variety of estuarine fish communities (Gilmore, 1977; Gilmore et al., 1983). Species richness in many of the fish communities of the estuary has declined since the 1970s when baseline data were collected. In addition to the general decline in species richness, specific fish communities appear to be affected by salinity and habitat changes. Submerged aquatic vegetation communities provide nursery ground habitat for juvenile stages of reef and recreationally important fishes in the St. Lucie Estuary (Lewis, 1984; Virnstein et al., 1983). This community includes mutton, yellowtail and lane snappers, yellowtail parrot fish, gag grouper, sailor’s choice grunt, tarpon, snook, jack crevalle, spotted sea trout, and redfish. Ichthyoplankton recruitment into the St. Lucie Estuary and the Indian River Lagoon is diminished due to flushing that results from regulatory discharges during key times of the year (Gaines and Bertness, 1992). Estuarine fish species that are negatively affected include spotted sea trout, snook, opossum pipefish, and lower trophic level fishes (Gilmore, 1999).

Woodward-Clyde (1994) noted that a shift in species composition of finfish appears to have taken place, with a higher proportion of lower priced species being taken more recently. The increased harvest of species such as menhaden and mullet may also have an effect on the overall ecology and productivity of the lagoon. One species, the spotted sea trout, showed significant decline (over 50 percent) in landings from 1962 to 1988.

Salinity Envelope

Results of this analysis indicated that the St. Lucie Estuary is very sensitive to freshwater input and that modifications to the volume, distribution, circulation, or temporal patterns of freshwater discharges can place severe stress upon the entire ecosystem (Steward et al., 1994). The SFWMD determined that an effort should be made to define the desired optimal salinity regime for the estuary for use as a management goal to guide long-term restoration efforts. Such restoration conditions are, however, distinctly different from the MFL criteria, which are intended to avoid significant harm.

Salinity patterns affect productivity, population distribution, community composition, predator-prey relationships, and food web structure in the inshore marine habitat. Salinity is the master ecological variable that controls important aspects of community structure and food web organization in coastal ecosystems (Myers and Ewel, 1990). In order to develop an environmentally sensitive plan for management of flows from the St. Lucie Estuary watershed, biological and physical information was needed to determine a desirable range of flows to the estuary. In 1975, the South Florida Water Management District (SFWMD) began baseline investigations to determine the seasonal presence of biota and to document the short-term reactions of estuarine organisms under various salinity conditions during controlled regulatory releases and watershed runoff events (Haunert and Startzman, 1980, 1985; Haunert, 1987). Based on these field investigations and subsequent modeling studies, a favorable range of flows, referred to as the "salinity envelope," was defined to occur in the St. Lucie Estuary when inflows were in the range from 350 to 2,000 cfs.

A more detailed understanding of flows is needed to develop a watershed management plan. The full range of natural intra- and interannual variation of salinity regimes, and associated characteristics of timing, duration, frequency, and rate of change, are critical in sustaining the full native biodiversity and integrity of estuarine ecosystems (Estevez, 2000). Better watershed flow distribution targets are needed to ensure the protection of the salinity-sensitive biota in the estuary. It is assumed that species diversity in the St. Lucie Estuary requires the hydrology to have characteristics of a natural system and that the monthly flow distribution is a critical hydrologic characteristic.

Protected Species

Southeastern Florida, in general, has a rich diversity of native flora and fauna. These include endemic and subtropical species that cannot be found anywhere else in the United States. The St. Lucie basin supports a diverse and abundant array of fish and wildlife species, including many endangered and threatened species (**Table 6**).

Table 6. Threatened, Endangered, and Species of Special Concern in Martin and St. Lucie Counties[a]

Common Name	Scientific Name	County[a]	Species Designation[cd] FWC	FDACS	USFWS	CITES
Mammals						
Florida mouse	*Podomys floridanus*	M,S	SSC			
Florida panther	*Felis concolor coryi*	M	E		E	
Sherman's fox squirrel	*Scuirus niger shermani*	M,S	SSC			
Southeastern beach mouse	*Permyscus polionotus niveiventris*	S	T		T	
West Indian manatee	*Trichechus manatus*	M,S	E		E	
Birds						
American oystercatcher	*Haematopus palliatus*	M,S	SSC			
Arctic Peregrine falcon	*Falco peregrinus*	M,S	E		T	
Audubon's crested caracara	*Polyborus plancus audubonii*	M,S	T		T	
Bald eagle	*Haliaeetus leucocephalus*	M,S	T		E	
Black skimmer	*Rynchops niger*	M,S	SSC			
Brown pelican	*Pelecanus occidentalis*	M,S	SSC			
Burrowing owl	*Speotyto cunicularia*	M, S	SSC			
Crested caracara	*Caracara plancus*	M, S	T		T	
Florida sandhill crane	*Grus canadenses pratensis*	M,S	T			
Florida scrub jay	*Aphelocoma coerulescens coerulescens*	M,S	T		T	
Least tern	*Sterna antillarum*	M,S	T			
Limpkin	*Aramus quarauna*	M,S	SSC			
Little blue heron	*Egretta coerulea*	M,S	SSC			
Osprey	*Pandion haliaetus*	S	SSC			
Oystercatcher	*Haematopus palliatus*	S	SSC			
Peragrine falcon	*Falco peragrinus*	M, S	E		E	
Piping plover	*Charadrius melodus*	M,S	T		T	
Reddish egret	*Egretta rufescens*	S	SSC			
Rivulus	*Rivulus marmoratus*	S	SSC			
Red-cockaded woodpecker	*Picoides borealis*	M	T		E	
Roseate spoonbill	*Ajaia ajaia*	M,S	SSC			
Snail kite	*Rostrhamus sociabilis plumbeus*	S	E		E	
Snowy egret	*Egretta thula*	M,S	SSC			
Southeastern American kestrel	*Falco sparverius paulus*	M,S	T			
Tricolor heron	*Egretta tricolor*	M,S	SSC			
White ibis	*Eudocimus albus*	M, S	SSC			
Wood stork	*Mycteria americana*	M,S	E		E	
Reptiles and Amphibians						
American alligator	*Alligator mississippiensis*	M,S	SSC			
Atlantic green turtle	*Chelonia mydas mydas*	M,S	E		E	
Atlantic hawksbill turtle	*Eretmochelys imbricata imbricata*	M	E		E	
Atlantic loggerhead turtle	*Caretta caretta caretta*	M,S	T		T	
Eastern indigo snake	*Drymarchon corais couperi*	M,S	T		T	

a. Source: Nature Conservancy, 1990; FGFFC, 1993; FDEP, 1991; Florida Natural Areas Inventory, 1998; FWS, 2001.

b. County: M = Martin; S = St. Lucie

c. Species Designation: **T** = threatened; **E** = endangered; **SSC** = species of special concern; **C** = commercially exploited species; **R** = species potentially at risk due to restricted geographic range/habitat or sparse distribution

d. Agencies: **FWC** = Florida Fish and Wildlife Conservation Commission – jurisdictional over Florida's animals (vertebrates and invertebrates); **FDACS** = Florida Department of Agriculture and Consumer Services – jurisdictional over Florida's plants; **USFWS** = United States Fish and Wildlife Service – jurisdictional nationally over plants and animals; **CITES** = Convention on International Trade in Endangered Species

Table 6. Threatened, Endangered, and Species of Special Concern in Martin and St. Lucie Counties[a] (Continued)

Common Name	Scientific Name	County[a]	Species Designation[cd] FWC	FDACS	USFWS	CITES
Florida pine snake	*Pituophis melandeucus mugitus*	S	SSC			
Gopher frog	*Rana capito*	M, S	SSC			
Gopher tortoise	*Gopherus polyphemus*	M,S	SSC			
Kemp's ridley	*Lepidochelys kempii*	S	E		E	
Leatherback turtle	*Dermochelys coriacea*	M,S	E		E	
Fish						
Atlantic sturgeon	*Acipenser oxyrinchus*	S	T			
Bigmouth sleeper	*Gobiomorus dormitor*	S	T			
Common snook	*Centropomus undecimalis*	M,S	SSC			
Lake Eustis pupfish	*Cyprinodon variegatus hubbsi*	S	SSC			
Mangrove rivulus	*Rivulus marmoratus*	S	SSC			
Mountain mullet	*Agonostomus monticola*	S	R			
Opossum pipefish	*Microphis brachyurus lineatus*	S	T			
River goby	*Awaous tajasica*	S	T			
Slashcheek goby	*Gobionellus pseudofasciatus*	S	T			
Spottail goby	*Gobionellus stigmaturus*	S	SSC			
Striped croaker	*Bairdiella sanctaeluciae*	S	SSC			
Plants						
Atlantic Coast Florida lantana	*Lantana depressa var Floridana*	M		E		
Banded wild-pine	*Tillandsia flexuosa*	M		E		
Bay cedar	*Suriana maritima*	S		E		
Beach jacquemontia	*Jacquemontia reclinata*	M		E	E	
Beach star	*Remirea maritima*	S		E		
Blunt-leaved peperomia	*Peperomia obtusifolia*	M,S		E		
Burrowing four-o'clock	*Okenia hypogaea*	M,S		E	E	
Butterfly orchid	*Encylia tampensis*	M,S		T		T
Cardinal Wild-pine	*Tillandsia fasciculata var. densispica*	S		E		
Carter's large-flowered flax	*Linum carteri var smallii*	M		E		
Catesby's lily	*Lilium catesbaei*	M,S		T		
Coastal hoary-pea	*Tephrosia angustissima var curtissii*	S		E		
Coastal vervain	*Glandularia maritima*	M,S		E		
Curtiss' milkweed	*Asciepias curtissii*	M,S		E		
Dollar orchid	*Encyclia boothiana var erythroniodes*	M		E		
Florida beargrass	*Nolina atopocarpa*	S		T		
Florida Keys ladies' tresses	*Spirantes polyantha*	M		E		
Florida tree fern	*Ctenitis sloanei*	M		E		
Four-petal pawpaw	*Asimina tetramera*	M		E	E	
Fragrant prickly apple	*Cereus eriophorus var fragrans*	S		E		

a. Source: Nature Conservancy, 1990; FGFFC, 1993; FDEP, 1991; Florida Natural Areas Inventory, 1998; FWS, 2001.

b. County: M = Martin; S = St. Lucie

c. Species Designation: **T** = threatened; **E** = endangered; **SSC** = species of special concern; **C** = commercially exploited species; **R** = species potentially at risk due to restricted geographic range/habitat or sparse distribution

d. Agencies: **FWC** = Florida Fish and Wildlife Conservation Commission – jurisdictional over Florida's animals (vertebrates and invertebrates); **FDACS** = Florida Department of Agriculture and Consumer Services – jurisdictional over Florida's plants; **USFWS** = United States Fish and Wildlife Service – jurisdictional nationally over plants and animals; **CITES** = Convention on International Trade in Endangered Species

Table 6. Threatened, Endangered, and Species of Special Concern in Martin and St. Lucie Counties[a] (Continued)

Common Name	Scientific Name	County[a]	Species Designation[cd]			
			FWC	FDACS	USFWS	CITES
Geiger tree	*Cordia sebestena*	S		E		
Giant leather fern	*Acrostichum danaeifolium*	M,S		T/C		
Giant wild-pine	*Tillandsia utriculata*	S		E		
Golden polypody	*Phlebodium aureum*	S		T		
Green ladies'-tresses	*Spiranthes polyantha*	M		E		
Hand adder's tongue fern	*Ophioglossum palmatum*	M,S		E		
Hand fern	*Cheiroglossa palmata*	M,S		E		
Inkberry	*Scaevola plumieri*	S		T		
Johnson' seagrass	*Halophila johnsonii*	S		T		
Lakela's mint	*Dicerandra immmaculata*	S		E	E	
Large flowered rosemary	*Conradina grandiflora*	M,S		E		
Low peperomia	*Peperomia humilis*	M		E		
Night scent orchid	*Epidendrum nocturnum*	M		T		
Nodding pinweed	*Lechea cernua*	M,S		E		
Non-crested coco	*Pteroglossaspis ecristata*	M		T		
Pepper	*Peperomia humilis*	M,S		E		
Pine pinweed	*Lechea divaricata*	M		E		
Rain lily	*Zephyranthes simpsonii*	M				
Redberry ironwood	*Eugenia confusa*	M		T		
Rigid epidendrum	*Epidendrum rigidum*	M		E		
Sand dune spurge	*Chamaesyce cumulicola*	M,S		E		
Sea lavender	*Argusia gnaphalodes*	M,S		E		
Shoestring fern	*Vittaria lineata*	S		T		
Simpson zephyr lily	*Sephyranthes simpsonii*	M		E		
Small's milwort	*Polygala smallii*	M		E		
Spotless - petaled baim	*Dicerandra immaculata*	S		E		
Tampa vervain	*Glandularia tampensis*	S		E		
Terrestrial peperomia	*Peperomia humilis*	M,S		E		
Tiny polygala	*Polygala smallii*	S		E	E	
Toothed habernaria	*Habenaria odontopetala*	S		T		T
Tropical ironwood	*Eugenia confusa*	M		E		
Twisted air plant	*Tillandsia flexuosa*	M		T		
Twistspine prickly pear	*Opuntia compressa*	S		T		T
Vanilla	*Vanilla mexicana*	M		T		
Venus hair fern	*Adiantum capillus-veneris*	M		T		
Wild coco	*Pterogiossaspis ecristata*	M		T		
Wild cocoa	*Eulophia alta*	M				
Wild pine	*Tillandsia balbisiana*	S		T		

a. Source: Nature Conservancy, 1990; FGFFC, 1993; FDEP, 1991; Florida Natural Areas Inventory, 1998; FWS, 2001.

b. County: M = Martin; S = St. Lucie

c. Species Designation: **T** = threatened; **E** = endangered; **SSC** = species of special concern; **C** = commercially exploited species; **R** = species potentially at risk due to restricted geographic range/habitat or sparse distribution

d. Agencies: **FWC** = Florida Fish and Wildlife Conservation Commission – jurisdictional over Florida's animals (vertebrates and invertebrates); **FDACS** = Florida Department of Agriculture and Consumer Services – jurisdictional over Florida's plants; **USFWS** = United States Fish and Wildlife Service – jurisdictional nationally over plants and animals; **CITES** = Convention on International Trade in Endangered Species

WATER RESOURCE ISSUES

This section summarizes the major water resource issues associated with management of the St. Lucie River and Estuary as identified in a conceptual model of the system.

Hydrologic Alteration of the Watershed

Due to Lake Okeechobee regulatory releases, basin flood releases, basin water withdrawals, and diversion of water from the natural river to the canals, freshwater flow distribution, volume, and timing in the St. Lucie River and Estuary watershed have been altered. Hydrologic alterations affect salinity and siltation patterns resulting in major ecological impacts to every component of the estuarine ecosystem.

Altered salinity patterns affect productivity, population distribution, community composition, predator-prey relationships, and the food web structure in the St. Lucie River and Estuary as evidenced by deteriorating oyster health and abundance, decline in benthic organisms, and the lack of significant submerged aquatic vegetation.

Extensive deposits of ooze and muck in the estuary are related to the transport of organic and inorganic sediments during regulatory and other high volume water releases from the canals. The ooze-covered bottom compromises oyster, fish, and benthic macro invertebrate habitat and has resulted in an increase in pollution-tolerant species. Submerged aquatic vegetation is also affected by the decreased light conditions resulting from siltation.

Input of Nutrients and Dissolved Organic Matter

Water quality within the St. Lucie River and Estuary is threatened by altered freshwater inputs, nutrient loss from agricultural activities, anthropogenic organic compounds, trace elements, and storm water runoff from developed areas. The system has experienced an 100 percent increase in phosphorus load and a 200 percent increase in nitrogen. The dramatic increase in nutrients and dissolved organics degrade water quality and may contribute to the buildup of muck. This results in changes in phytoplankton, macro algae, and submerged aquatic vegetation communities, and creates a generally favorable habitat for primarily pollution-tolerant organisms. The increased nutrients in the St. Lucie Estuary have increased primary productivity within the system to the point that unhealthy levels of dissolved oxygen occur on a regular basis in the inner estuary. The integrity of riverine and estuarine ecosystems is dependent on water quality. As water quality diminishes, so does the overall quality of the system.

Input of Toxins

The estuary has experienced increased input of toxins from agricultural runoff, urban development, and the boating industry. The presence of fish abnormalities and mortality has been noted in recent years. Bioaccumulation of toxins, including metals and pesticides, in the estuarine aquatic food chain may also have secondary effects on fisheating birds and dolphins. A decline in diversity of benthic organisms and the spread of pollution-tolerant macro invertebrates is an indicator of poor water quality in the estuary.

Recreational Use

Population increase in this region has fueled a rapid expansion of the boating and fishing industries resulting in ecological impacts to the St. Lucie River and Estuary. Increased pressure from recreational fisheries has contributed to the significant decline of species such as the spotted sea trout. The increased harvest of species such as menhaden and mullet has an impact on the ecology of the river and estuary.

Physical Alterations to the Estuary

Shorelines and intertidal areas of the estuary that were once populated by mangroves and other detritus producing vegetation now support very little vegetation. In many areas, sea walls and docks have replaced mangrove and sea grass habitats. The natural shoreline vegetation once helped stabilize the substrate, filter storm water runoff, and provide quality habitat. Further, unconsolidated sediments with high amounts of organic material have accumulated in the estuary and are frequently suspended by wave energy (Haunert, 1988). This sedimentation process has degraded habitat for bottom dwelling organisms and added to water quality problems. A significant portion of the floodplain of the North Fork of the St. Lucie River is completely or partially isolated from the river's main branch because of dredging conducted by the USACE during the 1920s through the 1940s. This isolation has compromised the system's nutrient filtering capability. Overall, these current conditions compromise the development of healthy biological communities and reduce the potential for sustaining these communities in the estuary.

Water Supply

Prior to large-scale citrus expansion in the 1960s, canal storage in St. Lucie County was adequate to meet irrigation demands. Subsequent drainage and development have depleted surface water storage while water management for flood protection has reduced ground water storage. The *Upper East Coast Water Supply Plan* (SFWMD, 1998a) analysis of surface water needs estimates that, by 2020, overall water demand is projected to increase by 34 percent. Annual surface water deficit estimates for a 1-in-10 year drought condition and projected demands are shown in **Table 7**. Unmet surface water needs were distributed to available ground water sources, primarily the Floridan Aquifer.

Development of water management and storage infrastructure to effectively capture and store the surface water flows in the St. Lucie basin were proposed in the *Upper East Coast Water Supply Plan* (SFWMD, 1998a) and the *Central and Southern Florida Project Comprehensive Review Study* (USACE and SFWMD 1999), also known as the Restudy. The facilities recommended in the Restudy are being refined and implemented through the CERP. With these facilities in place, the projected future (2020)

Table 7. Annual Surface Water Deficit Estimates for a 1-in-10 Year Drought Condition

Surface Water Basin	Acre-Feet	Millions of Gallons per Day
C-23 Canal	48,476	43.27
C-24 Canal	23,372	20.88
North Fork of the St. Lucie River	18,589	0
Tidal St. Lucie	0	0

surface water needs of the basin and the estuary can be met. The evaluated components, once constructed, would be adequate to meet the demands in the basin during a 1-in-10 year drought event.

Need for Maximum Flow Criteria

For both Lake Okeechobee and the St. Lucie River, floods or extended periods of high water result in the need to release large volumes of water to the St. Lucie Estuary for flood protection purposes. These high volume discharges have been shown to significantly impact the resource. Setting a minimum flow is viewed as a starting point to define the water needs of the estuary for sustainability. The necessary hydrologic regime for restoration of the regional ecosystem must also be defined and implemented through the use of water resource protection tools. Achieving the required water levels and flows through this system in an overall, long-term restoration goal of the CERP and the *Upper East Coast Water Supply Plan* (SFWMD, 1998a).

The maximum flow that should not be frequently exceeded for the estuary is 2,000 cfs. Rates above this amount often occur due to watershed flows alone. Even greater flows occur due to the Lake Okeechobee regulation schedule and pulse releases. The overall ability of the schedule to protect the resource is uncertain due to the limited water storage capacity of the regional system, especially during high rainfall years.

RESOURCE PROTECTION PROGRAMS

Indian River Lagoon SWIM Plan

The *Indian River Lagoon Surface Water Improvement and Management (SWIM) Plan* initially completed in 1989 (SFWMD, 1989) and updated in 1994 (SFWMD, 1994), addresses water quality concerns and environmental water supply needs by providing targets for freshwater inflows to the St. Lucie Estuary and the Indian River Lagoon. Planning and research conducted under the direction of the SWIM program have resulted in the development of a salinity range restoration target for the estuary. Related planning efforts are itemized in **Appendix G**.

Ten Mile Creek Project

The Ten Mile Creek Project is a Critical Restoration Project that was authorized by the United States Congress under Section 528 of the Water Resources Development Act of 1996. The intent of the Ten Mile Creek Project is to attenuate wet season storm water flows into the North Fork of the St. Lucie River from the Ten Mile Creek basin by capturing and storing storm water. The sedimentation of suspended solids will reduce sediment loads delivered to the estuary. The captured storm water will be passed through a polishing cell for additional water quality treatment before being released into the North Fork. Dry season discharge from the reservoir will serve the purpose of recharging local canals for irrigation, resulting in a reduced dependence on the Floridan Aquifer in this area. Construction is scheduled to begin in August 2002.

Indian River Lagoon Feasibility Study

To address the freshwater discharges to the St. Lucie Estuary and Indian River Lagoon, the SFWMD, in cooperation with the USACE, is conducting the Indian River Lagoon Restoration Feasibility Study (USACE and SFWMD, 2001) to investigate regional water resource opportunities in relation to the C&SF Project canal system. Regional attenuation facilities (surface water storage areas) and stormwater treatment areas designed to capture, store, and filter local runoff in the C-23, C-24, C-25, and C-44 basins were evaluated for their ability to attenuate flood flow to the estuary, provide water supply benefits, and provide water quality benefits to control salinity and reduce loading of nutrients, pesticides, and other pollutants contained in runoff presently discharged to the estuary. Contingent upon congressional authorization in 2002, project construction is scheduled to begin by September 2004.

The Indian River Lagoon Feasibility Study (USACE and SFWMD, 2001) refined the salinity targets established for the St. Lucie Estuary during Restudy alternative evaluations and identified an acceptable range of inflows to the estuary to meet targets of 350 cfs to 2,000 cfs (USACE and SFWMD, 1999). Research conducted to establish these inflow targets for the St. Lucie Estuary provided baseline assumptions for MFL technical criteria development, including the understanding that “native aquatic biodiversity depends on maintaining or creating 'some semblance' of natural flow variability, and that native species and natural communities will [may] perish if the environment is [consistently] pushed outside the range of natural variability” (Haunert and Konyha, 2001).